Retrofit Emission Control Technologies for On- and Off-Road Diesel Vehicles

Manufacturers of Emission Controls Association

California Air Resources Board

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Presentation Outline

- Introduction
- Background
- Retrofit Control Technologies
- Elements of Retrofit Program
- Cost Effectiveness
- Conclusions

The Emission Challenge Is Complex

- Current Standards Focus on HC, NOx, PM, and CO
- However:
  - Toxic Emissions Are Obtaining More Attention
  - Particle Number Issues
  - Three Major Species of NOx
  - PM
    - many species, size range <10 nm to >2 microns, number, liquid and gaseous HCs, solid carbon, carbon/organic combinations and sulfur oxides

Can All Facets of the Diesel Emissions Issue Be Addressed?

- Are Control Technologies Available to Remove Both Diesel PM and the Other HC-Based Toxic Emissions?
- Are These Control Strategies Compatible with Further Reductions in NOx Emissions?

Yes, If an Integrated Approach Is Used -
Advanced Engines, Integrated Emission Control Technologies, and Clean Fuels

Available Retrofit Technologies

- PM, CO, HC and Toxics
  - Diesel Oxidation Catalyst (DOC)
  - Diesel Particulate Filters (DPF)
  - Enhanced Combustion Modifications (e.g., cams, coatings, superchargers)
  - Biodiesel and Alternative Fuels (used with DOC)
  - Fuel Borne Catalysts with Exhaust Emission Controls

Available Retrofit Technologies (cont'd)

- NOx
  - SCR (can provide reduction in other pollutants as well)
  - Systems Strategies (engine modifications plus PM exhaust controls)

Retrofit Experience

- Mining
- Materials Handling
- Truck and Bus
- Marine Vessels and Locomotives
- Stationary Diesel Engines

Diesel Oxidation Catalysts Are Efficient and Have Excellent Operating Experience

- Oxidation Catalyst Control Capabilities
  - PM -- 20-50% Reduction
  - CO and HC -- >90%
  - Toxic HCs -- >70%
- Oxidation Catalyst Operating Experience
  - >20,000 Urban Buses in the U.S. and Europe
  - >3,000 HD Vehicles in Mexico
  - Hong Kong Is Retrofitting 1,800 Urban Buses
  - >250,000 Nonroad Engines

Diesel Particulate Filters Are Efficient and Are Developing an Impressive Track Record

- Filter Control Capabilities
  - PM -- >80% Reduction
  - CO and HC -- >90%
  - Toxic HCs -- >90% Reduction
- Filter Operating Experience
  - Over 10,000 Systems Haave Retrofitted to Vehicles Worldwide
  - Peugeot Will Offer Filter-Equipped LDVs in 2000
  - Over 10,000 Non-Road Engines Equipped (Both OE Installed and Retrofit)

SCR Has Been Used Successfully on Stationary Sources and Is Now Used for Mobile Sources

- SCR Control Capabilities
  - PM – 30-50% Reduction
  - CO and HC -- >80%
  - Toxic HCs – >80%
  - NOx – 60 - >80%
- SCR Operating Experience
  - 18 HD Trucks Demonstrated in Europe since 1995 with Mileage Exceeding 200,000 miles
  - Over 20 Marine Vessels since mid-1990s
  - Some Use on Locomotives

Other NOx Control Technologies

Technology	Performance Range			
	NOx	CO	HC	PM
Active Lean NOx	25-50	>70	>70	~ 30
NOx Adsorber	50-70	>70	>70	> 30
Plasma / NOx Cat.	>65	>50	>50	~ 30

NOx Technologies Are in Various Stages of Development

- Passive Lean-NOx Catalysts Used on PC in Europe
- NOx Adsorbers Are in Vehicle Trials
- Plasma Technology Is in the Laboratory Stage and Emerging on Vehicles

Air Enhancement Technologies Can Be Used to Reduce Emissions on Existing Vehicles

- Electronic Supercharger Control Capabilities
  - PM – 50% Reduction when Used with an Oxidation Catalyst
  - CO and Visible Smoke Can Be Reduced
- Electronic Supercharger Operating Experience
  - 250 Units Installed on Urban Buses in the U.S.
  - Installed on HD Vehicle Applications in the U.S., Canada, Mexico, England, Germany, France, Russia, Brazil, and New Zealand

Other Retrofit Options Can Be Used to Reduce Emissions on Existing Vehicles

- Heat Recuperator Combined with Catalyst Technology for Reductions in CO, HC, Toxics, NOx, and PM

Overview of Retrofit Programs

- U.S. EPA Mandatory Urban Bus Retrofit/Rebuild Program
- U.S. EPA Voluntary Retrofit Program
- ARCO/ARB/CEC Low Sulfur Demonstration
- Sweden's Clean Cities Retrofit Program
- London Bus and Truck Program

Overview of Retrofit Programs (cont'd)

- New York City Retrofit Demonstration Program
- NESCAUM/NEP/MECA Nonroad Equipment Pilot Demonstration Program
- Boston Central Artery/Tunnel Project Retrofit Program
- German Central City/Tunnel Clean Diesel Program

Overview of Retrofit Programs (cont'd)

- Retrofit of Tunnel Construction Equipment in Germany, Austria and Switzerland
- Retrofit Programs in Korea, Taiwan, Mexico, El Salvador, Nicaragua, and Hong Kong
- Filter Program Started In Paris

Elements of a Proper Retrofit Control Program

- Size
  - Properly Sized Control Technologies Insure Low Backpressure and Maximum Performance
- Vehicle Integration
  - An Important Aspect of Control Technology Retrofit, but Has Been Successfully Accomplished on Both On- and Off-Road Vehicles (muffler replacement or in-line installation)
- Fuel Quality
  - For PM Control, <10 ppm Allows for Maximum Emission Control Performance and Best Filter Regeneration Characteristics
  - Oxidation Catalysts Can Be Formulated to Minimize Sulfation, but at the Expense of Some Reduced Emission Control Performance
  - Some Filter Technologies Can Be Applied to Some Applications Using Fuels with Sulfur Levels Found in California

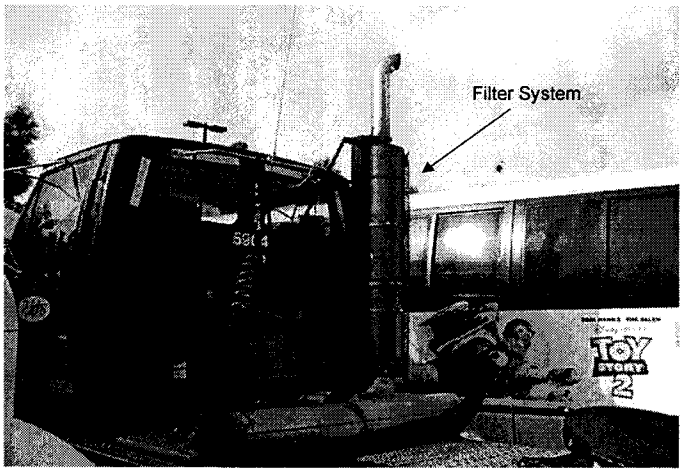
Current Cost Effectiveness

- Filter Technology
  - Depends on Engine Size -- Approximately $10 - $20/bhp
  - 2 Hours for Installation
  - Ash Removal at ~60,000 Miles
- Oxidation Catalyst Technology
  - Approximately $1,000 - $2,000 per Vehicle Depending on Type of Vehicle Integration
  - 2 Hours for Installation
  - No Maintenance

Current Cost Effectiveness (cont.)

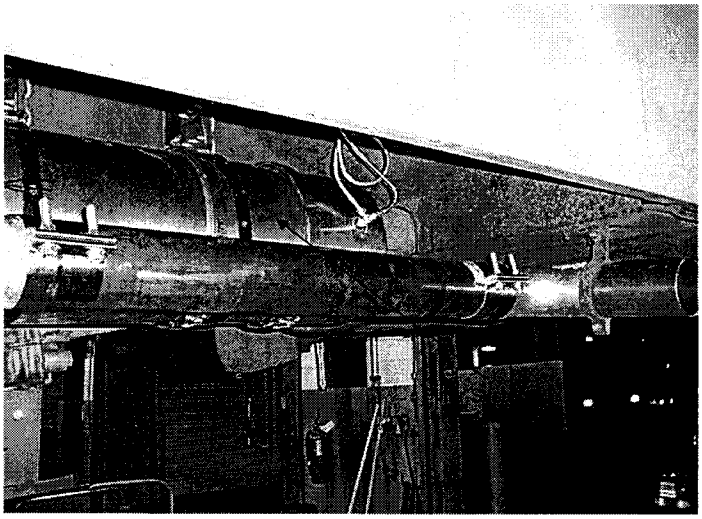
- SCR
  - Approximately ~$15,000 -$20,000 per Vehicle Assuming a Fleet Operator Equips a Number of Vehicles
  - 2 Days for Installation
  - Reagent Consumed at 6% of Fuel Consumption (depending on conversion efficiency, engine type, etc.)
- MECA Is Currently Carrying Out an Independent Cost Study
- Costs for Filters, Oxidation Catalysts and SCR Will Decrease as Sales Volumes Increase.

Filter System Retrofitted to a Truck

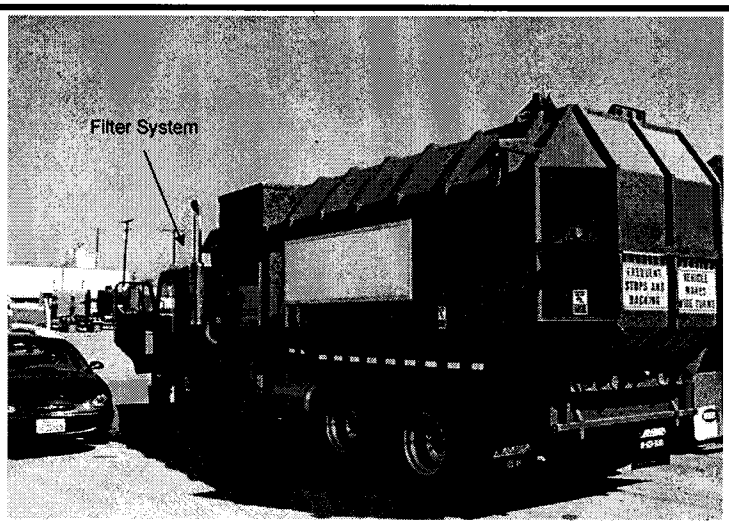


Filter System Retrofitted to a Bus

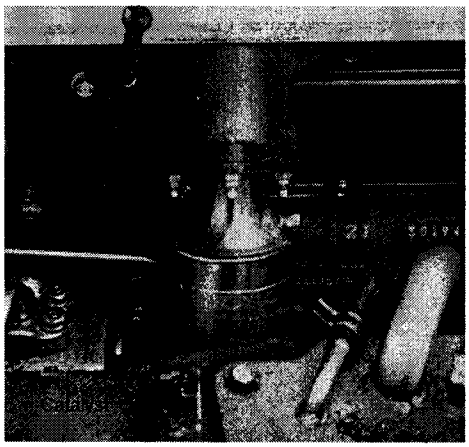
Filter System Retrofitted to a Bus



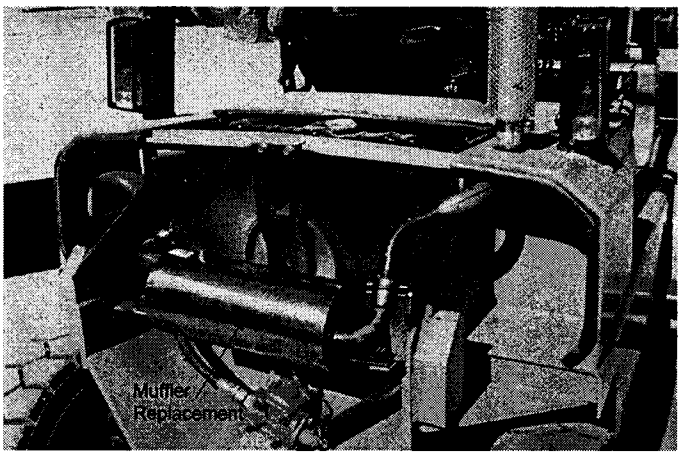
Filter System Retrofitted to a Refuse Truck



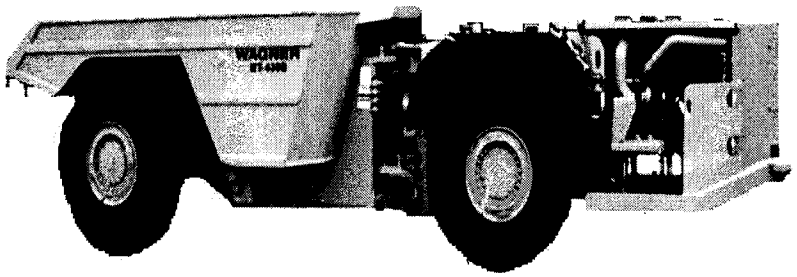
Direct Fit In-line Converter



Integrated Converter Muffler



Both Oxidation Catalysts and Diesel Particulate Filters Have Been Extensively Retrofitted to This Type of Mining Vehicle



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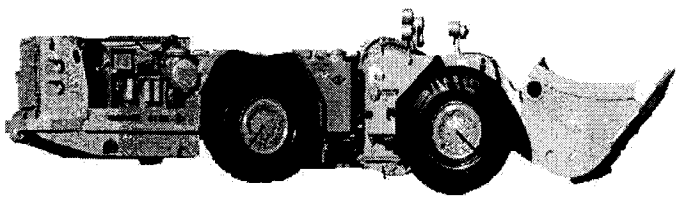
ST8-B Scooptram



Testing of An Oxidation Catalyst on a FEL

Central Artery/Tunnel Project (Big Dig)

Conclusions

- Existing Heavy-Duty Diesel Engines Are a Significant and Growing Source of NOx, PM, and Toxic Emissions
- A Variety of Demonstrated Technologies are Available to Significantly Reduce Emissions from Existing HDDEs
- A Growing Number of Retrofit Programs Are Being Successfully Implemented

Conclusions (cont'd)

- Diesel Emission Retrofit Control Technologies Are Effective in Reducing PM, NOx, HC, CO, Odor, Smoke, and Toxics Emissions